CONTROL DEVICE FOR HYBRID COMPRESSOR

BACKGROUND OF THE INVENTION

The present invention relates to a hybrid compressor in use for an air-conditioner system in an idle stop vehicle or a hybrid vehicle and more particularly relates to a control device for the hybrid compressor that compresses refrigerant gas by power from an electric motor even when an engine is stopped.

Japanese Unexamined Utility Model Publication No. 6-87678 generally discloses a hybrid compressor. A compression unit in the hybrid compressor is selectively driven either by a vehicle engine or an electric motor. Power is transmitted between the engine and the compression unit through an electromagnetic clutch. When air-conditioning is unnecessary or when the compression unit is driven by the electric motor, the electromagnetic clutch is in a blocking state or de-energized so that the engine power is not transmitted to the compression unit.

Meanwhile, due to static friction of sliding portions and compressed liquid refrigerant that has been accumulated in compression chambers of the compression unit, a starting torque of the hybrid compressor is larger than a stationary torque that is required for driving the hybrid compressor at a stationary

operation state. To transmit a torque corresponding to the starting torque of the hybrid compressor, an electromagnetic clutch exerts a connecting force or a combining power that is large enough to maintain the contact between the power source and the hybrid compressor. That is, a value of electric current is applied to the electromagnetic clutch to generate the above-described connecting force. The constant electric current value for the starting torque is applied to electromagnetic clutch in prior art. However, when the compressor is driven at the stationary operation state by the engine, the torque of the compressor is reduced, and the necessary connecting force is also reduced. Thus, while the compressor is driven at the stationary operation state by the engine, the electromagnetic clutch consumes unnecessary electric power.

SUMMARY OF THE INVENTION

The present invention provides a control device that reduces a starting torque of a hybrid compressor upon an engine drive.

In accordance with the present invention, a control device is used for a hybrid compressor that has compression chambers to compress refrigerant gas. A certain amount of liquid refrigerant in the compression chambers causes a maximum starting torque of the compressor. The compressor is selectively driven by a vehicle engine through an electromagnetic clutch and by a compressor

electric motor. The control device includes a motor driver for driving the electric motor, a clutch controller for driving the electromagnetic clutch and an engine drive timing controller. Power is transmitted from the engine to the compressor when the electromagnetic clutch is connected. The clutch controller sets a connecting force of the electromagnetic clutch to transmit a second starting torque of the compressor. The engine drive timing controller is electrically connected to the motor driver and the clutch controller. The engine drive timing controller commands the motor driver to activate the electric motor to discharge the liquid refrigerant from the compression chambers to a predetermined level so that the compressor reduces its starting torque to the second starting torque before commanding the clutch controller to connect the electromagnetic clutch to transmit the power from the engine to the compressor.

The present invention also provides a method for controlling a hybrid compressor in an air-conditioner system from a stop state. A certain amount of liquid refrigerant in the compression chambers causes a maximum starting torque of the compressor. The compressor is selectively driven by a vehicle engine through an electromagnetic clutch and by a compressor electric motor. The method includes the step of setting a first value of electric current applied to the electromagnetic clutch to be smaller than a second value of the electric current that generates a connecting force of the electromagnetic clutch for transmitting a maximum starting torque of the compressor. The first value enables the power

transmission from the engine to the compressor at a second starting torque with the liquid refrigerant at a predetermined level in the compression chambers. The method also includes the steps of driving the compressor only by the electric motor from the stop state for a predetermined amount of time, discharging the liquid refrigerant to a predetermined level from the compression chambers, applying the first value of the electric current to the electromagnetic clutch and transmitting power from the engine to the compressor through the electromagnetic clutch.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1 is a longitudinal cross-sectional view of the compressor according to a preferred embodiment;

FIG. 2 is a graph showing compressor torque and the contrast between the preferred embodiment and a prior art device in electric current applied to the

electromagnetic clutch;

FIG. 3 is a flow chart illustrating steps involved in a preferred process of controlling the drive source for the compressor according to the present invention; and

FIG. 4 is a longitudinal cross-sectional view of the compressor according to a first alternative embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment according to the present invention will now be described. First, a hybrid compressor will be schematically described. As shown in FIG. 1, a hybrid compressor C constitutes a part of a refrigerating cycle of a vehicle air-conditioner system for compressing refrigerant gas and includes a housing 11. The housing 11 accommodates an electric motor 12 and a scroll type compression unit 13. An engine E for driving a vehicle is operatively connected to the compression unit 13.

The compressor C includes the electric motor 12. The compressor C is selectively driven by the electric motor 12 and the engine E. When the engine E is not rotating in a stop state, the compression unit 13 is driven by the electric motor

12. Thereby, the compression unit 13 compresses the refrigerant gas even when the engine E is in the stop state. The air-conditioner system in the present preferred embodiment is suitable for an idle stop vehicle or a hybrid vehicle.

Next, the compressor C will be described in detail. A rotary shaft 14 is rotatably accommodated in the housing 11. The electric motor 12 includes a rotor 15 and a stator 16. The rotor 15 is rotatably fixed to the rotary shaft 14. The stator 16 is fixedly arranged on the inner circumferential surface of the housing 11 so as to surround the rotor 15. The electric motor 12 rotates the rotor 15 and the rotary shaft 14 when electric power is supplied to the stator 16.

An electromagnetic clutch 17 is arranged on a power transmission path between the compressor C and the engine E. The electromagnetic clutch 17 is rotatably supported at the outside of the housing 11 and includes a rotor 19, a hub 20, an armature 22 and a magnetic coil 23. The rotor 19 is coupled to a belt 18 that transmits power from the engine E. The hub 20 is fixed to the rotary shaft 14. The armature 22 is supported by the hub 20 through an elastic member 21. The magnetic coil 23 is supported by the housing 11. The elastic member 21 exerts elastic force to separate the armature 22 from the rotor 19.

When an electric current is applied to the electromagnetic clutch 17 to energize the magnetic coil 23, a suction force based on an electromagnetic force

is applied to the armature 22. Accordingly, the armature 22 moves against the elastic force of the elastic member 21 to press-contact the end surface of the rotor 19. The rotor 19 is electrically connected to or temporarily combined with the armature 22 by a press-contacting force corresponding to a value of the electric current that is applied to the magnetic coil 23. When the electromagnetic clutch 17 is in a connecting state, the electromagnetic clutch 17 transmits power from the engine E to the rotary shaft 14.

Then, when the magnetic coil 23 is de-energized, the electromagnetic suction force that has been applied to the armature 22 dissipates. Accordingly, the armature 22 moves due to the elastic force of the elastic member 21 to separate from the end surface of the rotor 19 in a blocking state. That is, the connection between the rotor 19 and the armature 22 is released. When the electromagnetic clutch 17 is in the blocking state, the electromagnetic clutch 17 does not transmits the power form the engine E to the rotary shaft 14 and also does not transmit unnecessary power from the electric motor 12 to the engine E.

The compression unit 13 includes a fixed scroll member 25 having a fixed spiral wall 25a and a fixed base plate 25b as well as a movable scroll member 26 having a movable spiral wall 26a and a movable base plate 26b. The fixed scroll member 25 is fixedly arranged in the housing 11. A crankshaft 14a is secured to the end surface of the rotary shaft 14. The movable scroll member 26

is supported by the crankshaft 14a so as to rotate relative to the fixed scroll member 25. The fixed spiral wall 25a of the fixed scroll member 25 engages with the movable spiral wall 26a of the movable scroll member 26. The distal end surfaces of the fixed spiral wall 25a and the movable spiral wall 26a respectively contact the movable base plate 26a and the fixed base plate 25a. Accordingly, compression chambers 27 are defined by the fixed spiral wall 25a and the fixed base plate 25b of the fixed scroll member 25 as well as the movable spiral wall 26a and the movable base plate 26b of the movable scroll member 26.

The refrigerant gas is introduced into the compression chambers 27 from a suction chamber 28 that is defined in the housing 11. As the compression chambers 27 are moved inwardly by the orbital movement of the movable scroll member 26 relative to the fixed scroll member 25 based on the rotation of the rotary shaft 14, the compression chambers 27 reduce their volume. Thereby, the refrigerant gas is compressed to a predetermined pressure value in the compression chambers 27. When the compression chambers 27 have approached the center of the fixed scroll member 25, the compressed refrigerant gas is discharged from the compression chambers 27 into a discharge chamber 29 that is defined in the housing 11.

Next, a control device for controlling the compressor C will be described in detail. Still referring to FIG. 1, the control device for the compressor C includes

an air-conditioner ECU 51, an information detector 52 that provides information to the air-conditioner ECU 51, a motor driver 53 for driving the electric motor 12 and a clutch controller 54 for driving the electromagnetic clutch 17. The air-conditioner ECU 51 is electrically connected to the motor driver 53 and the clutch controller 54. The air-conditioner ECU 51 functions as an electronic control unit that is similar to a computer. The air conditioner ECU 51 communicates with an engine ECU 61 which functions as an electronic control unit similar to a computer. The information detector 52 includes switches and sensors, which are not shown, such as an air-conditioner switch, a temperature sensor and a temperature-setting device for detecting all kinds of information for the air-conditioning.

A starting torque of the compressor C is defined as a torque required from a stop state for initially rotating the compression unit 13 and other associated sliding portions that constitute the compressor C. The maximum value of the starting torque is determined based on the structure of the vehicle air-conditioner system, the structure of a vehicle that utilizes the vehicle air-conditioner system and the use environment. The starting torque of the compressor C is substantially at the maximum when a relatively large amount of liquid refrigerant has been accumulated in the compression chambers 27 of the compression unit 13.

As shown in FIG. 2, assuming a large amount of accumulated liquid

refrigerant in the compression chambers 27, a value of the electric current I1 applied to the electromagnetic clutch 17 is conventionally determined in such a manner that a connecting force of the electromagnetic clutch 17 is large enough to transmit a maximum starting torque A of the compressor C as indicated by a dotted line. In the present preferred embodiment, before the engine E drives the compression unit 13, the electric motor 12 drives the compression unit 13 from a stop state to discharge the accumulated liquid refrigerant from the compression chambers 27 during an EM drive period. One definition of the duration of the EM drive period or a predetermined amount of time Tm is an amount of time for the electric motor activation that is necessary to minimize the remaining amount of the liquid refrigerant in the compression chambers 27 after which the remaining amount remains constant. After the liquid refrigerant discharge is substantially completed, the compressor C halts its rotation. After a predetermined amount of time, the electric motor 12 is stopped, and the engine E now drives the compressor C during an engine drive period. Thus, the subsequent starting torque of the compressor C is reduced from the maximum starting torque A to a predetermined minimal torque which is defined as a second starting torque B. Due to the predetermined minimal second torque B of the compressor C, the necessary connecting force of the electromagnetic clutch 17 is correspondingly relatively small as indicated by a reduced amount of current I2. Therefore, the clutch controller 54 sets the value of the electric current I2 applied to the magnetic coil 23 in such a manner that the connecting force of the electromagnetic clutch

17 is smaller than a maximum starting connecting force required for transmitting the maximum starting torque A of the compressor C. Namely, the value of the electric current I2 applied to the magnetic coil 23 is smaller than the above conventional value I1, but the connecting force of the electromagnetic clutch 17 is large enough to transmit the second starting torque B that is slightly larger than a stationary torque C required for driving the compressor C at a stationary operation state. Meanwhile, when the stating torque of the compressor C is the maximum starting torque A due to the accumulated liquid refrigerant in the compression chambers 27 of the compression unit 13, it is difficult to steadily start the compressor C by the engine E due to sliding of connecting portions in the electromagnetic clutch 17.

The air-conditioner ECU 51 gives commands to the motor driver 53 and the clutch diver 54 according to the operational requirements of the compressor C based on the air-conditioning information from the information detector 52 and according to operational information on the engine E offered from the engine ECU 61. When the vehicle is in an idle stop state or when the engine E is in a stop state, the air-conditioner ECU 51 commands the clutch controller 54 to block the electromagnetic clutch 17 or to de-energize the magnetic coil 23 according to the operational requirements of the compressor C based on the air-conditioning information from the information detector 52. In addition, the air-conditioner ECU 51 commands the motor driver 53 to drive the electric motor 12 based on the

same information. Therefore, the compression unit 13 is driven by the electric motor 12.

On the other hand, when the vehicle is in a traveling state or when the engine E is in a running state, the air-conditioner ECU 51 commands the clutch controller 54 to connect the electromagnetic clutch 17 or to energize the magnetic coil 23 according to the operational requirements of the compressor C based on the air-conditioning information from the information detector 52. In addition, the air-conditioner ECU 51 commands the motor driver 53 to stop the electric motor 12 or to de-energize the stator 16 based on the same information. Therefore, the compression unit 13 is driven by the engine E.

In the process where the compression unit 13 is initially driven by the electric motor 12 and then substantially driven by the engine E, the air-conditioner ECU 51 functions as an engine drive timing controller and performs unique control as shown in flow chart in FIG. 3 according to a pre-stored program.

The air-conditioner ECU 51 judges whether or not the engine E is in the running state or an ON state in step (hereinafter referred to as S) 101. If the judgment is NO in the S101 because the engine E is not in a running state, the process proceeds to "return." If the judgment is YES in the S101 because the engine E is in the running state, the process proceeds to S102. The

air-conditioner ECU 51 judges in the S102 whether or not the operation of the compression unit 13 or the air-conditioner system is required based on the air-conditioner information from the information detector 52. If the judgment is NO in the S102 since the operation of the compression unit 13 is not required, the process proceeds to "return."

On the other hand, if the judgment is YES in the S102 because the operation of the compression unit 13 is required, the process proceeds to S103. The air-conditioner ECU 51 commands the motor driver 53 to activate the electric motor 12 in S103. Thereby, the electric motor 12 is activated to drive the compression unit 13. When a relatively large amount of the liquid refrigerant is accumulated in the compression chambers 27 after the vehicle has stopped for a relatively long period of time, at least a part of the liquid refrigerant is discharged to the outside due to the action of the compression unit 13 or the orbital movement of the movable scroll member 26 relative to the fixed scroll member 25. In S104, the air-conditioner ECU 51 monitors whether or not the predetermined amount of time Tm has elapsed since the activation of the electric motor 12. The predetermined time Tm is a required amount of time to discharge large amount of the liquid refrigerant in the compression chambers 27 so as to reduce the starting torque of the compressor C from the maximum starting torque A to the second starting torque B that is steadily transmitted by the electromagnetic clutch 17.

If the judgment is YES in the S104 because the electric motor 12 and the compression unit 13 have operated for the predetermined time Tm, the air-conditioner ECU 51 commands the motor driver 53 to stop or turn off the electric motor 12 in S105. After the electric motor 12 is stopped, the air-conditioner ECU 51 commands the clutch controller 54 to connect or turn on the electromagnetic clutch 17 from the blocking state in S106. Thus, the electromagnetic clutch 17 transmits the power from the engine E to the compression unit 13, and the compression unit 13 is driven by the engine E.

As described above, the clutch controller 54 sets the connecting force of the electromagnetic clutch 17 to be smaller than the maximum starting connecting force. However, since the substantial amount of the liquid refrigerant is discharged from the compressor C by the activation of the electric motor 12, the starting torque of the compressor C is reduced without the initial large amount of the liquid refrigerant in the compression chambers 27. Therefore, even though the connecting force of the electromagnetic clutch 17 is relatively small due to the relatively small value of the electric current, the electromagnetic clutch 17 transmits the sufficient power from the engine E to the rotary shaft 14 to steadily drive the compressor C from the stop state.

According to the present preferred embodiment, following advantageous effects are obtained and described with respect to FIGs. 1 through 3. (1) Before

the compression unit 13 is driven by the engine E, the air-conditioner ECU 51 commands the motor driver 53 to activate the electric motor 12 to drive the compression unit 13. A major portion of the existing liquid refrigerant is discharged from the compression chambers 27 of the compression unit 13 due to the orbital movement of the movable scroll member 26 relative to the fixed scroll member 25. A substantial amount of the liquid refrigerant no longer exists in the compression chambers 27 when the engine E starts to drive the compression unit 13. Therefore, as shown in FIG. 2, the starting torque of the compressor C is smaller for the engine E than that before discharging the liquid refrigerant.

(2) The clutch controller 54 sets the connecting force of the electromagnetic clutch 17 to be smaller than for the maximum starting torque A of the compressor C. That is, the value of the electric current applied to the electromagnetic clutch 17 is smaller than the conventional value as shown in FIG. 2. Thus, electric power consumption of the electromagnetic clutch 17 is substantially reduced. In the preferred embodiment, since the starting torque of the compressor C is reduced for the engine E, the electromagnetic clutch 17 provides the sufficient connecting force with the reduced electric power consumption for transmitting the torque that is smaller than the maximum starting torque A of the compressor C.

(3) The air-conditioner ECU 51 commands the motor driver 53 to stop

the electric motor 12 before commanding the clutch controller 54 to connect the electromagnetic clutch 17. Thus, when the electromagnetic clutch 17 is connected and the compression unit 13 is driven by the engine E, the compressor C is in the stop state in which a relatively large amount of a torque is required for starting the compressor C. However, in the present preferred embodiment, the starting torque of the compressor C has been substantially reduced from the maximum starting torque A by the electric motor 12 before the electromagnetic clutch 17 is connected for the engine E to drive the compression unit 13. Thus, even though the electromagnetic clutch 17 provides the relatively small connecting force, the compressor C is steadily driven at an initial stage from the stop state before reaching the stationary state. Therefore, it is especially effective to reduce the stating torque of the compressor C before the engine E starts to drive the compressor C from the stop state.

According to the present invention, the following alternative preferred embodiment is practiced. In the above-described preferred embodiment, before the compression unit 13 is driven by the engine E, the compression unit 13 is driven by the electric motor 12. However, as shown in FIG. 4, a judgment means is electrically connected to the air-conditioner ECU 51 for judging whether or not the liquid refrigerant is accumulated in the compression chambers 27 in a first alternative embodiment. Only when the judgment means judges that the liquid refrigerant is equal to or more than a predetermined amount in the compression

chambers 27, the engine drive timing controller commands the motor driver 53 to activate the electric motor 12 to drive the compression unit 13 before the engine E drives the compression unit 13. If the vehicle has been in the stop state at least for a predetermined period of time since switching off a vehicle-start switch, the judgment means judges that the predetermined amount of the liquid refrigerant exists in the compression chambers 27.

With respect to FIG. 3, the S105 and the S106 in the above-described preferred embodiment are changed in a second alternative process. Namely, the electric motor 12 is stopped after the electromagnetic clutch 17 is connected. The rotor 19 or a first rotor is rotated in accordance with the rotation of the engine E, and the hub 20 or a second rotor is rotated integrally with the rotary shaft 14 in accordance with the rotation of the rotary shaft 14. The rotor 19 and the hub 20 constitute a connecting portion of the electromagnetic clutch 17. The air-conditioner ECU 51 receives information on a rotational speed of the engine E from the engine ECU 61. In reference to the information on the rotational speed of the engine E, the air-conditioner ECU 51 adjusts a rotational speed of the electric motor 12 through the motor driver 53 to substantially correspond to the rotational speed of the rotor 19. In this way, the rotational speed of the rotor 19 is substantially the same as that of the hub 20. In this state where a rotational speed of the rotor 19 from the engine E is substantially the same as that of the hub 20 from the compression unit 13 in the connecting portion of the electromagnetic

clutch 17, the electromagnetic clutch 17 is connected. Thereby, shock upon the connection is substantially prevented.

The present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.